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Geophysical resistivity survey (VES) for selection of appropriate artificial recharge (Ar) structures for augmentation of groundwater resources in Gwalior, M.P, India

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ABSTRACT

In this study, the data generated while conducting electrical resistivity surveys through Vertical Electrical Sounding (VES) at six random sites in different location along with available geological & hydro-geological information of parts of Gwalior city were analyzed. The objectives are (i) to understand the nature and extent of aquifer, (ii) to find out the location and thickness of unsaturated zones and (iii) to evaluate the possibility of appropriate artificial recharge structures at suitable locations across the city.

Interpretation of the sounding curves indicates presence of three to four subsurface geo-electric layers across the study area. The top soil layer has a range of resistivity values from 2 to 30-ohm m & lithologically comprises clay / clay with kankar, lateritic sand. This is followed by the weathered and jointed shale layers with resistivity values 30-100-ohm m. A third layer of hard and compact shale with resistivity values 100–300-ohm m could be identified below a depth of about 45 m. At some places, doleritic dykes were also observed with resistivity values > 300-ohm m.

The interpretation of VES data when correlated with the available litholog data indicates a prominent water bearing zone between 30 and 45 mbgl. The underlying hard and compact shale has very little possibility of occurrence of ground water. The top unsaturated and unconfined granular zone up to a depth of 30 mts could therefore be easily recharged artificially through rainwater harvesting measures, thereby augmenting the groundwater resources of the existing aquifers. Site specific artificial recharge measures from amongst contour bundings, gully plugs, check dams, percolation tank, recharge shafts & subsurface dykes have been identified across the city for effective recharge of the aquifer especially in its north eastern (Morar block) & southern regions. Considering the deteoriating groundwater situation, these initiatives would be significant in catering to the needs of the future generations.

Keywords: Rainwater Harvesting, Artificial Recharge (AR), Vertical Electrical Sounding (VES), Well-Siting, ABEM Terrameter –SAS 300, Litholog, Morar Shales, Schlumbger Configuration.

1. INTRODUCTION

Groundwater, a vital resource for life is of limited extent and requires to be managed well. Due to the factors like high population growth, large scale urbanization and erratic rain fall patterns over the years there has been a stressing demand of the quantity and quality of this natural resource. The availability of water from sub-surface storage (groundwater) varies considerably as the amount of percolation varies greatly from region to region and even within the same region from place to place depending upon the amount and pattern of rainfall, characteristics of soil and rocks, the nature of terrain and other climatic factors like evapo-transpiration, temperature and humidity etc. In Gwalior like most low rain fall areas of the country; the availability of utilizable surface water is so low that people have to depend largely on groundwater for agricultural and domestic uses. Excessive groundwater pumping in such low rain fall areas and other drought prone districts of Madhya Pradesh for the mentioned usage has resulted in alarming decline of groundwater levels. The large-scale growth of mega cities has further compounded the problem due to drastically reducing open lands areas for natural recharge. In such a condition for improving the groundwater situation, it is necessary to artificially recharge the depleted groundwater aquifers. The available techniques must be easy, cost-effective and sustainable in the long term.

The major objective of the study was to understand the nature of aquifer formation in the area and its thickness other than siting of new borewell for domestic and commercial purposes. Keeping these objectives in mind, the present work has been carried out. Number of researchers successfully used the electrical methods for groundwater prospecting and selection of artificial recharge structures in various terrains. Some of them are Zody et al., (1974), Das et al., (2007) etc who have very clearly brought out the relationship between electrical and hydraulic properties of the aquifers.

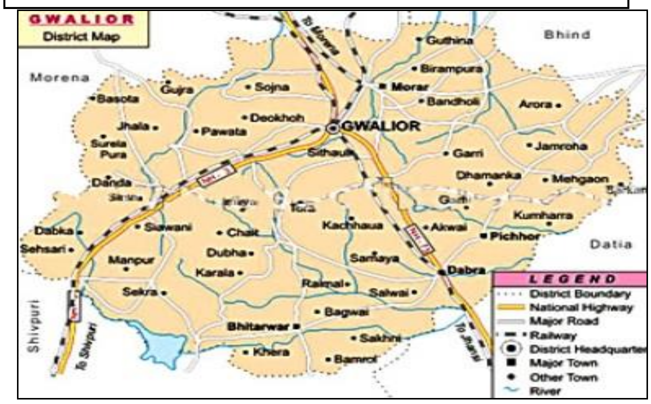
2. ELECTRICAL RESISITIVITY METHOD

Electrical resistivity method is of foremost importance in groundwater exploration, in water quality evaluation and groundwater pollution studies because the resistivity of a rock is very sensitive to its water content. Although several methods can be enumerated under the geophysical method, the electrical resistivity method has been used in the present investigation. Some of the common sedimentary rocks being more porous possess higher water content; hence they normally have lower resistivity values. Wet and clayey soils normally have a lower resistivity than sandy soils. Resistivity of each rock type depends on certain characters such as porosity, degree of water saturation and concentration of dissolved salts (Kearey and Brooks 1988).

3. THE STUDY AREA

The study pertains to different locations in Gwalior which is an historical place & important city of Madhya Pradesh. It is surrounded by District Morena in the North, District Shivpuri in the south, District Bhind in the East and District Datia in the west. The District is having two sub-divisions, namely, Gwalior & Dabra. There are three tehsils, namely, Gwalior,
Dabra & Bhitarwar and four Development Blocks namely, Ghatigaon (Barai), Morar, Dabra & Bhitarwar. It is well connected with all the major cities of India by road, rail and also with air.

Map of Gwalior



3.1 Specific area of investigation

The study areas comprised of the following locations (mostly covers North eastern– East- South eastern side) spread across the district Gwalior (refer Map of Gwalior). Following are the specific locations where the surveys were conducted and the generated data was used for the analysis and subsequent preparation of this article.

(1) Mr. Vinod Sharma land at village Bilaua of Jorasi block, Gwalior (nearly 5 km from Dabra-Jhansi Road)

(2) Mr. Om Khandelwal, Brick Kiln operating land at village Kush Rajpura of Piprali Panchayat, Gwalior (nearly 3 kms from Shivpuri- Link Road and on way to the famous Shitla Mata Temple.

(3) At the proposed site of upcoming Loha Mandi on Shivpuri- Link Road Shivpuri Link Road, Ghatigaon block, Gwalior for Ms.Chouhan Construction

(4) ITM Universe, Global Business School campus is located at Gwalior Jhansi Road- Bhind bypass and is approximately 18.5 kms away from Gwalior city.

(5) District Horticulture Department, Gwalior- New Location at Nurabad Farm (Riyaru-Banmore) adjacent to AB Road and opposite to JK Tyres Plant in Gwalior district bordering Morena.

(6) Jiwaji University Campus, Gwalior

3.2 Topography

The areas investigated were mostly topographically flat to semi-undulating terrain.

3.3 Climate & Rainfall

The area experiences a semi-arid climate marked by extreme temperature and variability of rainfall. May & June are the hottest months of the year with the temperature ranging from 30°C to 48° C, January, on the other hand is the coldest month with temperature ranging between 4° C to 25° C.

It can be noticed from the annual rainfall data that the pattern of rainfall is erratic. The rainfall generally increases from north to south. The average annual rainfall is about 650-700 mm.

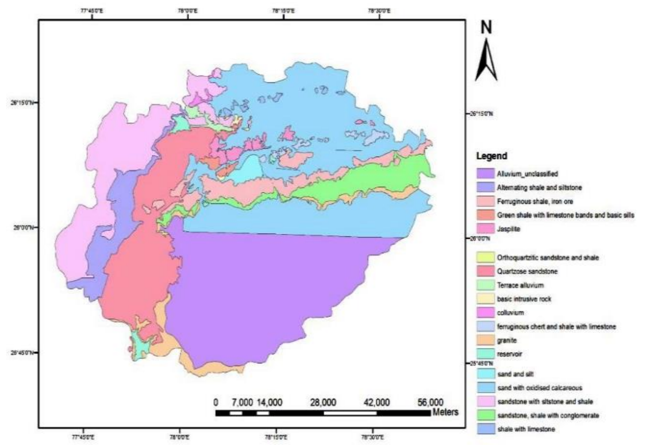
3.4 Soil

The soil in the district is light in texture, sandy loam and clay loam.

3.5 Geology

Geologically, the area is characterized by the Gwalior Group of rocks resting unconformably over Bundelkhand granite and comprise of basal arenaceous Par Formation overlain by Morar Formation consisting of ferruginous shale with bands of chert, jasper and limestone (refer map). The area is covered by alluvium, shale and sandstone.

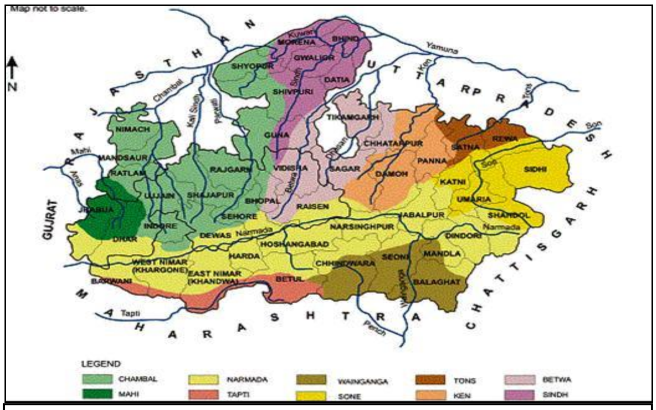
Among these lithounits, alluvium is the main target of the area for groundwater exploration and storage purposes. It covers most of the northern part of the Morar block with more or less plain area. Shale is a potential lithounit in the area and because of clayey composition it has very low infiltration capacity leading to higher rate of runoff. It also covers the southern as well as central part of the area in the form of residual hills at topographic high.



Geological Map of the Gwalior Area

4. WATER SOURCES

Gwalior falls in Kali Sindh river basin (refer map) in M.P which is basically water scarce region due to its geographical set-up.



River Basins of M.P

The water supply system in Gwalior is mainly dependent on the Tighra-Kaketo system and groundwater augments this supply.

The supplies from Tighra dam located on the Sank River are supplemented by supply from another reservoir of the Kaketo dam on Narver River. The water supply in the area is done through the surface water supply system and tube wells. Tighra reservoir is the main source of water for drinking purpose in the area managed by Municipal Corporation in urban area and Panchayats in the rural area.

A significant volume of ground water is also extracted through a network of borewells, hand pumps, tubewells for various purposes. Groundwater is the major source of water for drinking and domestic purposes in areas where water supply system is not operating. Other than this groundwater is excessively extracted for commercial purpose also. Though the condition has not yet got poorer but considering factors like rapid population growth, erratic rainfall, urbanization etc if measures are not adopted, the situations is ought to become alarming. This emphasizes and necessitates the need for adopting extensive RWH & artificial recharge measures in Gwalior and country at large.

5. HYDROGEOLOGY OF THE INVESTIGATED AREA

The selected areas are located across Gwalior city. Geologically, the area mainly consists of alluvium underlain by Morar shales of Gwalior group. The sand and gravel in alluvium and weathered & jointed Morar shales form the principal aquifers in the area.

Occurrence, movement and distribution of the groundwater are chiefly controlled by degree and depth weathering. Generally, quality of water is good. Flouride, iron and nitrate contamination can be found at few places.

The exploratory drilling was carried out in the Jiwaji University Campus by the Central Groundwater Board to understand the nature and extent of shallow and deeper aquifers. The litholog of the exploratory well is given in the (Table-1) with depth range in meter below ground level (mbgl), thickness and inferred lithology of the area.

Table 1. Lithological log of the exploratory well

S. No	Depth Range (mbgl)	Thicknes s (m)	Lithology
1	00 – 21.3	21.3	Clay: Yellow, sticky, plastic mixed with calcareous kankar and mudcracks.
2	21.3 – 24.4	3.1	Clay: Reddish brown, sticky mixed with calcareous kankar and Morar shale.
3	24.4 -36.5	12.1	Shale; Greenish brown and mixed with greenish brown jasper, highly weathered and jointed.
4	36.5 – 57.7	21	Shale: Grey and mixed with brown jasper, moderately weathered and jointed.
5	57.7 – 76.2	18.5	Shale – Greyish black, hard and compact, thinly bedded.
6	76.2 – 128.1	51.8	Shale: black, hard and compact
7	128.0 – 34.2	6.1	Dolerite: Black, hard and compact, coarse grained with pyrite.
8	164.7– 179.9	15.2	Shale: Greyish black, hard and highly jointed, thinly bedded.
9	179.9 – 228.7	48.8	Dolerite: Black, hard and compact very coarse grained.
10	228.7 – 231.8	3.1	Shale: Black, hard and compact, mixed with dolerite.
11	231.8 – 281.6	49.8	Shale; Coal black, hard and compact.
12	281.6 – 290.7	9.1	Shale; Brownish black, hard and jointed with bands of jasper.
13	290.7– 296.7	6.0	Shale: grey and mixed with reddish jasper, highly jointed.
14	296.7 -305	8.7	Shale; black, hard and compact

Source: CGWB

Based on the interpretation of litholog data of the area the first water bearing zone was encountered between 30 and 40 mbgl in alluvium.

Electrical resistivity survey method- a brief overview:

Electrical Resistivity Survey comprises the following set of steps:

5.1 Hydro-geological investigation

The hydro-geological investigation includes the observation of local geological setup and the Hydro-geological properties of rocks such as recharge rate: well yielding capacity: pre-monsoon and post monsoon fluctuations: behavior of wells: attitude of rock formations thickness of overburden.

5.2 Geophysical investigations

Geophysical investigations were carried out by electrical resistivity method, using the instrument named ABEM Terrameter –SAS 300. The method for investigation is vertical electrical sounding (VES) by Schlumbger configuration. By way of conducting such sounding at different litho layers beneath the ground were probed to under stand the thickness and apparent resistivity of each litho – layers and its capacity to bear water.

Appropriate nos. of soundings is done at the project location for getting lithological characteristics variation with depth.

5.3 Analysis of VES data

The obtained readings in the field are plotted in the bi-logarithmic graph sheet and the geo-electric field curve were interpreted and correlated with standard two layers master curves (Orellana and Mooney) by partial curve matching techniques to ascertain the water bearing strata beneath the earth. The same was also cross- checked with computer software WINSEV 6.

5.4 Suggestion and recommendation

Finally, the recommendation and suggestion are made based on the hydro geological investigation of the area and subsequent geophysical data interpretation which clearly indicates the layer resistivity ρ1, ρ2, ρ3 & ρ4 and its thickness.

6. GEOPHYSICAL SURVEY (VES) CONDUCTED FOR THE STUDY

For the study, Vertical electrical sounding (VES) surveys had been carried out at 6 locations using Schlumberger electrical resistivity techniques to ascertain the nature of bedrock below the soil cover, and to delineate the layer thickness of different formations and resistivity contrast of different layers. The obtained data from the field were analyzed and interpreted to ascertain the water bearing strata beneath the earth. The analyzed data parameters from the different selected locations are given Table-2.

Table 2. Analyzed Data parameter

Apparent Resistivity (ohm-m)				**Thickness (m)**			
ρ1	**ρ2**	**ρ3**	**ρ4**	**h1**	**h2**	**h3**	**h4**
1. Mr. Vinod Sharma land at village Bilaua (near Jorasi village), Dabra block, Gwalior (nearly 5 km from Dabra-Jhansi Road)							
26	34	150	250	2	15	33	-
26	38	180	290	2	17	34	-
2. Mr. Om Khandelwal's Brick Kiln operating land at village Kush Rajpura of Piprali Panchayat, Gwalior (nearly 3 kms from Shivpuri- Link Road and on way to the Shitla Mata Temple							
13	11	14.5	25	2	18	30	-
3. At the proposed site of Loha Mandi on Shivpuri- Link Road Shivpuri Link Road, Ghatigaon block, Gwalior for Ms.Chouhan Construction.							
13.5	36.5	22.5	40	2	8	38	-
4. ITM Universe, GBS campus is located at Gwalior Jhansi Road-Bhind bypass and is approximately 18.5 kms away from Gwalior city.							
48	45	23	30	3	12	40	-
5. District Horticulture Department, Gwalior - New Location (Nurabad Farm) at Riyaru-Banmore area adjoining AB Road and opposite to JK Tyres Plant in Gwalior district bordering Morena.							
41	28	18	35	2	8	50	-
6. Jiwaji University Campus, Gwalior							
38	29	22	35	2	13	45	-

where,

ρ1-ρ5 Apparent Resistivity of each litho layer in ohm-m

h1- h4 Thickness of each layer in m

From the survey data analysis, majorly K and KHK types of curves were found in the area indicating the presence of multilayered inhomogeneous formation (Refer Table-3). Top layer is soil with resistivity values 2 to 30-ohm m and inferred lithology is predominantly clay / clay with kankar, lateritic sand. This is followed is the weathered and jointed shale layers with resistivity values 30 -100-ohm m and a third layer is hard and compact shales with resistivity values 100 – 300 ohm m. At some places, doleritic dykes were also observed with resistivity values > 300 ohm–m.

Table 3. Electrical parameters &hydrological significance

S No	Resistivity (Ohm-m)	Thickness (M)	Inferred Lithology	Hydrological Significance
1	2- 30	2 -40	Predominantly clay/ clay with kankar, lateritic sand	Generally, lies in unsaturated zone, aquifer at good upper level. & poor at depth.
2	30 - 100	5 -50	Highly weathered & jointed shale	Principal aquifer of the area.
3	100 - 300	0 - 48	Hard & compact shale	Poor aquifer
4	> 300	Bottom Layer	Shale hard and compact traversed by dolerite dykes	Very poor aquifer, act as barrier for ground water movement

7. RESULTS AND DISCUSSION

The analyses of sounding curves obtained from geophysical survey data over the areas have brought out three to four subsurface geo-electric patterns. The top layer (depth range- 2 to 20 m) consists predominantly of clay / clay with kankar/ loose lateritic sand followed in respective order by highly weathered & jointed shale (depth range- 20-55 m) and hard & compact shale (depth below 55 m) which at depth (>300) is traversed by dolerite dykes. These findings on being correlated with the results of CGWB litholog data pertaining to the study area shows broad similarity.

Major part of the investigated area are potential zones for ground water exploration and exploitation purposes and for long term sustainability these areas have sufficient scope for artificial recharge predominantly through the construction various appropriate water harvesting structures.

8. CONCLUSION AND RECOMMENDATIONS

As discussed above, it is concluded that field geo-electrical survey is very rapid and reliable method to explore an area for finding out the prospect of groundwater occurrence. It helps to delineate the area precious for groundwater development and management. Based on the above field survey and subsurface aquifer conditions, most of the areas need artificial recharge of the aquifers by adopting appropriate measures.

Following suggestions or recommendations have been proposed for groundwater development in the city.

A well-planned recharge scheme for the entire city should developed for the construction of various artificial recharge structures such as injection wells, recharge shafts, storage ponds and tanks etc. at suitable locations.

(1) In addition to new bore wells, defunct bore wells and dry wells in the surrounding area could be used for rainwater collection.

(2) Rooftop and paved rainwater harvesting should be compulsorily (legislation) done for large department / institutional buildings of the city.

(3) The rainwater collected should be put to desiltation and filtration prior to transporting down the earth through existing or newly constructed later harvesting structures like dug wells, bore wells, shafts, trenches etc.

(4) A detailed water management plan for the entire city is required to be prepared for utilizing the maximum quantity of the available surface (rainwater) resource which is currently going to waste. From the carried studies the broad description of the groundwater development and management plan envisaged for Gwalior is as under:

9. OVERALL GROUNDWATER DEVELOPMENT AND MANAGEMENT PLAN

The number of water harvesting structures should be distributed dividing balance resources equally for dug wells and tube wells and taking consideration of 100 % development of net groundwater availability in the block. Therefore, it is suggested that a scientific study at every five years' period is a must to check the impact of groundwater development on groundwater regime and accordingly number of structures should be modified. By considering these points, there are many ways to adopt this practice but the structures which are feasible in the study area & almost across Gwalior are: contour bundings, gully plugs, check dam, percolation tank, recharge shafts & subsurface dykes.

Broadly, the area for artificial recharge have to be divided into two categories i.e. overexploited and safe to semi-critical area where long term trends of groundwater level is declining. It is observed that gully plugs and contour bunds may be constructed on the upper reaches of streams. Percolation tanks can be considered in areas which provide sufficient spread. In locations where streams are of 5-6 m wide and have sufficient depth, a series of small check dams in the stream course may fulfill the objective of conservation of groundwater. During rainy season, it should be mandated that the farmers use bunds in the area for storing the water in their fields. In areas where clay beds that prevent percolation of water to the unsaturated zone in the weathered shale and granites, recharge shaft may prove good structures for artificial recharge of groundwater. In the alluvial flat terrain areas, due to very poor drainage density the feasibility of percolation tanks is almost remote. In these areas where the phreatic aquifer has gone dried and the clay beds do not allow percolating the water in deeper level, recharge shaft is only means to be adopted to augment the groundwater.

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ABBREVIATION

AR	Artificial Recharge
CGWB	Central Ground Water Board
RWH	Rain Water Harvesting
VES	Verical Electrical Sounding